

Heating Systems for Apple-Washing Machines

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Heating Systems for Apple-Washing Machines

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HEATING SYSTEMS for apple-washing machines are attracting increasing attention from apple growers. One reason for this is that the practice of washing apples when preparing them for market has become much more widespread than formerly. In Illinois, apple washers were first used by a few growers to improve appearance and increase the market value of the fruit. They are now necessary, as a rule, to permit apples to move in interstate, international, or, in Illinois and certain other states, in intrastate commerce.

Recent state, national, and foreign legislation limiting the amount of lead and arsenic that can be present on fruit moving across state and national boundaries has imposed upon many growers the necessity of removing practically all spray residues from their fruit. In attempting to remove these spray residues, growers have resorted to the use of brushes, sprays, and a variety of chemical washing solutions and wetting agents. When sufficient residue cannot be removed by these means, heat must be added to the solution to accelerate the chemical reaction¹ and improve the action of the wetting agents. Consequently the choice of appropriate heating systems to meet the requirements of individual growers, and the installation of the heating systems in such manner as to secure the most effective and economical service from them, are important problems facing many growers of apples.

EFFECTIVE TEMPERATURES OF WASHING SOLUTIONS

Before choosing a heating system and planning its installation, it is important to know something of the relative effectiveness, for residue removal, of a washing solution used at different temperatures. Experiments have shown that from two to six times as much lead and arsenical residue remains on apples washed at 70° F. as on those

¹Chemical reactions proceed more rapidly at high than at low temperatures. The increase in speed of reaction follows a fairly definite law. For each increase of 18° F. the rate of most reactions is doubled or tripled.

washed in the same type of washer at 110° F.¹ Thus, as a general rule, heat is required for effective washing if the fruit carries a heavy load of residue, or if washing is to be carried on under conditions which would result in the solution being much colder than 70° F.

The maximum washing temperature that can be used without danger of seriously damaging the fruit has been found by various workers to vary with the length of time the fruit is immersed, the strength of the acid solution, the variety of fruit washed, the use of a wetting agent, and various other factors. Until further studies have been made, 90° F. should apparently be considered the maximum safe temperature² for washing green apples or summer apples. In washing later varieties, temperatures of 110° F. for acid solutions and 125° F. for sodium silicate solutions are approximately the highest that can safely be used.

TYPES OF HEATING SYSTEMS

Heating systems for warming washing solutions are of three kinds—electric, steam, and hot water. Each has certain characteristics which make it especially adaptable to certain conditions. If an alkali solution is to be used, the choice of a system will depend entirely on the preference of the grower. When an acid solution is to be used, however, the choice is limited by problems of corrosion (see pages 25-26).

Each grower faced with the problem of choosing one of these three types of heating systems, or a modified form of one of them, should consider the desirable features and the limitations of each and then select the one that best meets his particular needs. The general characteristics of the several types are listed below. It is of course impossible to describe fully each type in relation to the widely varying conditions found in practice, but the following list gives the principal desirable features and limitations. (Detailed instructions for installing the various systems are given on pages 7 to 30.)

ELECTRIC SYSTEMS

Desirable features

1. Adapted to small and medium-sized heating loads.
2. Minimum amount of labor required during operation.
3. Accurate temperature control possible.
4. Minimum installation space required in solution tank.
5. Heating units available in wide range of sizes and types.

¹Ruth, W. A., and Kadow, K. J., "Spray Residue Removal," mimeo. pub., Ill. Agr. Exp. Sta., Jan. 2, 1935.

²Ruth, W. A., and Kadow, K. J., Unpublished data. Ill. Agr. Exp. Sta.

6. Additional heating units readily added later (if power line is sufficiently large).
7. No smoke, coal, or ashes around washing shed.

Limitations

8. Heat from electric energy may be expensive.
9. Service charge during idle months adds to operating cost.
10. Qualified electrician required for installation.

LIVE-STEAM SYSTEMS*Desirable features*

1. Adapted to large heating loads.
2. No metal parts in washing solution.
3. Low installation cost.
4. Boiler can be located at any level and at any distance from washer.
5. Heating capacity limited only by size of boiler.
6. Condensing steam tends to maintain level of washing solution constant.

Limitations

7. Strength of washing solution continually decreased by condensing steam.
8. Water must be added to boiler frequently to replace loss from steam.
9. Some danger of explosion involved, unless boiler is operated properly.

CLOSED STEAM-RADIATOR SYSTEM*Desirable features*

1. Adapted to large heating loads.
2. Smaller and shorter radiator pipe¹ required than for hot-water systems.
3. Practically no danger of explosion if system is properly installed.
4. More uniform temperature control possible than with other steam systems.

Limitations

5. Boiler must be located at least a specified distance below level of radiator pipe.

OPEN-END STEAM-RADIATOR SYSTEM*Desirable features*

1. Adapted to large heating loads.
2. Smaller and shorter radiator pipe required than for hot-water systems.
3. Boiler can be located at any level and at any distance from the washer.

Limitations

4. Water must be added to boiler frequently to replace loss from steam.
5. Some danger of explosion unless boiler is operated properly.

DIRECT-HEATING HOT-WATER SYSTEM*Desirable features*

1. No radiator pipes required.

Limitations

2. Acid solutions corrode iron pipe and heaters.
3. Alkali solutions clog heaters and pipes.
4. Circulating pump and driving mechanism required.

¹In this publication the term "radiator pipe" is used to designate the pipes, placed in the washing solution, thru which steam or hot water flows as a means of heating the solution.

GRAVITY-FLOW HOT-WATER SYSTEM*Desirable features*

1. Adapted, in general, to the smaller heating loads.
2. Temperature control comparatively easy.
3. No circulating pump required.
4. Has some natural regulating characteristics.

Limitations

5. Larger and longer radiator pipe required than for any other radiator system
6. Greater care required in design and installation than for any other system.
7. Heater must be located at least a certain distance below level of radiator pipe.

FORCED-CIRCULATION HOT-WATER SYSTEM*Desirable features*

1. Adapted, in general, to any size of heating load.
2. Heater can be located on any level and at any distance from washer.
3. Smaller and shorter radiator pipe required than for gravity-flow systems.

Limitations

4. Larger and longer radiator pipe required than for steam heating systems.
5. Circulating pump and driving mechanism required.

CONDITIONS USED AS BASES FOR DESIGN

On the following pages the various heating systems are described and instructions are given for correct installations designed to maintain washing solutions at the proper temperature in apple-washing machines of the common sizes and types on the market at the present time. In order that the instructions presented may be usable in making installations under all conditions of apple washing likely to be met by Illinois orchardists, certain conditions of temperature and speed of operation were arbitrarily selected as bases of design. The resulting installations are capable of meeting satisfactorily the greatest heat load likely to be required. The initial cost of such installations may be somewhat higher than the cost of installations designed to meet particular local conditions. Because the capacity of a heating system (except electric systems) cannot readily be changed after the system has been installed, it is advisable for the grower to make the necessary larger initial investment and be assured of an installation that will give complete satisfaction under all conditions.

The conditions of temperature arbitrarily selected as bases of design were the following:

- 110° F. to be maintained in all solution tanks except primary (alkali) tanks.
- 125° F. to be maintained in primary (alkali) tanks.
- 40° F. temperature of outside air and of fruit entering the tanks.

Furthermore, in order that the heating systems might be designed to meet adequately the washing operations requiring the greatest amount of heat, calculations were made of the total heat required for each washer operating at maximum capacity at each of a series of speeds. In this way it was found that more heat was required when a great many apples were given a brief washing, than when fewer apples were given a longer treatment. Consequently the minimum immersion time for which a washing-solution temperature of 110° F. would be likely to be required was selected¹ for each washer and used as the basis of design.

ELECTRIC SYSTEMS

Heating Capacity

When the grower has decided to install electric heating units, he should ascertain the total heating capacity² required for the type of washer to be used (Table 1). The sum of the heating capacities of the units selected for use with a given washer should be at least equal to, if not somewhat greater than the corresponding value in Table 1.

Some growers who wish to install electric heating systems may find it necessary (because of size of power line available, for example) or economical (because of operating conditions more favorable than those used herein as bases of design) to install a heating system smaller than that specified for a given washer. This substitution should not be attempted unless it is certain that the conditions to be met will be more favorable than those upon which Table 1 is based. If the grower is sure that the minimum temperatures of the fruit and the outside air at his plant will be higher than 40° F. at all times when the plant is in operation, or that it will not be necessary to heat the washing solution to temperatures as high as 110° F. in order to adequately remove the spray residue from his apples, he may profitably install a smaller system. In that case the number of kilowatts of heating capacity needed may be determined as follows:

Subtract the lowest temperature of fruit and air that will be experienced from the highest solution temperature that will be required. Divide this difference by 70 (the difference between 110° and 40° F.). Multiply the product by the number of kilowatts (listed in Table 1) for the given washer. The result will be the number of kilowatts required under the conditions of operation to be met by the grower.

For example: A model "AA" flood-type washer may be in use in

¹On basis of work by W. A. Ruth and K. J. Kadow, Ill. Agr. Exp. Sta.

²Electric heating elements are rated in kilowatts.

TABLE 1.—KILOWATTS OF ELECTRIC POWER NEEDED TO MEET HEAT REQUIREMENTS OF DIFFERENT MODELS AND SIZES OF APPLE-WASHING MACHINES

Model	Type	Dimensions of acid compartment				Heat requirement, per hour	Kilowatts needed to meet heat requirement
		Tank		Tray			
		Width	Length	Width	Length		
		<i>inches</i>	<i>inches</i>	<i>inches</i>	<i>inches</i>	<i>B.t.u.</i>	<i>kw.</i>
USDA.....	Flotation.....	34	171	....	....	178 361	52.2
Z.....	Flotation with pump.....	24¼	109	....	....	83 055	24.3
X.....	Flotation with pump.....	46	132	....	....	216 944 ^a	63.5
E.....	Underbrush flood.....	45	39¼	....	....	86 494	25.3
F.....	Underbrush flood.....	44¾	58¼	....	....	126 111 ^a	36.9
H.....	Underbrush flood.....	56½	81½	....	....	192 836	56.5
A.....	Flood.....	49½	54	....	....	86 405	25.3
AA.....	Flood.....	49½	54	....	....	82 353 ^a	24.1
AD.....	Flood.....	68	54	....	....	113 646 ^a	33.3
ADA.....	Flood.....	68	54	....	....	108 459 ^a	31.7
B(31).....	Flood.....	49½	54	....	....	82 353 ^a	24.1
B(34).....	Flood.....	68	44	64¾	10¼	100 683 ^a	29.5
C or CB (31)...	Flood or underbrush flood..	60½	41 ⅝	57¼	43	145 091	42.5
C or CB (34)...	Flood or underbrush flood..	68	44	64¾	32¼	154 754 ^a	45.3
D or DB (31)...	Flood or underbrush flood..	66	48	62¾	61½	204 050	59.8
D or DB (34)...	Flood or underbrush flood..	68	44	64¾	62¾	209 269 ^a	61.3
BDP, 1st tank..	Flood.....	68	43¼	64¾	4½	116 579 ^a	34.1
BDP, 2d tank..	Flood.....	68	44	64¾	3½	95 734 ^a	28.0
CDP, 1st tank..	Flood.....	68	43¼	64¾	32½	187 681 ^a	55.0
CDP, 2d tank..	Flood.....	68	44	64¾	6	109 179 ^a	32.0
DDP, 1st tank..	Flood.....	68	43¼	64¾	60½	253 164 ^a	74.1
DDP, 2d tank..	Flood.....	68	44	64¾	21	143 885 ^a	42.1

^aHeat loss from washers alone estimated from values obtained for washers of same type but different size.

an area where the temperature of air and fruit will not be below 50° F., and other conditions may be such that the residue can always be removed by a solution at a temperature not higher than 100° F. The proper heating capacity of an electric heating system for these conditions would be found as follows:

$$100^{\circ} - 50^{\circ} = 50^{\circ}$$

$$50^{\circ} \div 70^{\circ} = 5/7$$

$$5/7 \times 24.1 \text{ kilowatts (from Table 1)} = 17.2 \text{ kilowatts}$$

Several Heaters Usually Desirable

The number and size of heating units to be installed to supply a given total number of kilowatts depends upon the type of control to be used. *If an automatic control device is to be used*, the required total heating capacity should be specified to the company furnishing the control device. The advice of that company should then be followed as to the number and size of units to be installed, for the size of unit that can be controlled by a given control device is definitely fixed. Where

a large total heating capacity is required, some of the heaters should be controlled by hand in order to keep the cost of the automatic control device within reasonable limits.

Where the heaters are to be controlled entirely by hand, it is advisable to use several small heaters so that the heating system may be sufficiently elastic to meet changing demands upon it. One or more large heaters, of 5 to 8 kilowatts capacity each, should be used with two or more smaller heaters. The same result may be obtained by installing large units so constructed that they can be operated at half as well as at full capacity.

Installing the Heating Units

Improperly installed electric heating units in apple-washing machines are dangerous. *Heating units should be installed by qualified electricians*. It is particularly important that the installation be correctly and carefully made because the heaters located in a water bath are operated by men working on a wet floor.

As an additional safety measure, the switch box should be so located that the operator is forced to stand on a raised dry wood or rubber-covered platform to operate the switches. All switch boxes, metal conduits, and heater jackets should be well grounded so as to prevent accidents in case corrosion or damage causes any of these parts to become short-circuited.

Heaters should be so located in the tanks as to provide a uniform temperature thruout the washing solution. In nonagitating machines they should be placed at three or more points in the tank, and in agitating machines at the region of greatest flow of liquid. To facilitate this even distribution of heat, pencil type heaters may be used instead of strip heaters. Lead-covered heaters should not be used. All heaters should preferably be located near, but at least an inch from, the bottom of the tank.

Encrustation and Corrosion

When used in certain chemical solutions, such as sodium silicate, electric heaters become encrusted with layers of precipitated chemical substances. This surface film prevents rapid transmission of heat and thereby causes the heater to operate at temperatures higher than would otherwise occur. Unless this encrustation is removed frequently, the life of the heater will be materially shortened.

Heaters are subject not only to encrustation, but to corrosion from the chemical solutions in which they operate. When heaters

are ordered, the company supplying them should be informed of the chemicals to be used in the washing solution and asked to guarantee the heaters against corrosion for a specified period of time.

STEAM SYSTEMS

Steam heating systems for apple washing solutions are of two general kinds—those which enter the steam directly into the washing solution (the “live-steam” system), and those which use radiator pipes.

Live-Steam System

The live-steam system, used by many of the large central washing plants in the West, is the cheapest system to install, and is the only kind of steam or hot-water heating system that does not require the use of some type of metal pipe in the washing solution (Fig. 1). One

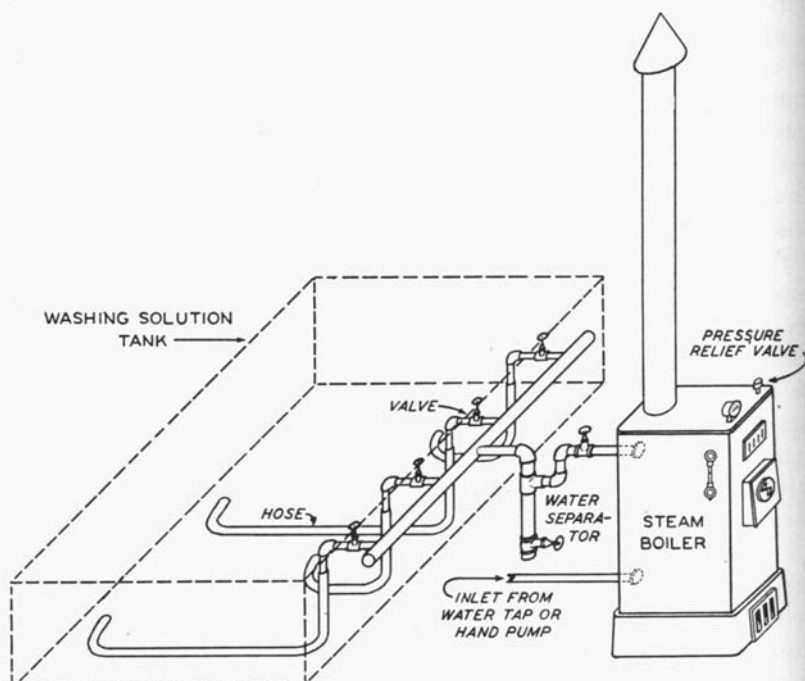


FIG. 1.—DIAGRAMMATIC VIEW OF A LIVE-STEAM HEATING SYSTEM

An objectionable feature of this type of heating system is the addition of condensed steam to the washing solution. The use of a water separator as shown here is particularly important when the steam supply pipe is long or poorly insulated. The pipes between the water separator and the solution tank, at least, should be well insulated.

important disadvantage of the live-steam system compared with steam-radiator systems, however, is that the addition of live steam to the washing solution dilutes the solution with approximately one gallon of water for each 9,000 B.t.u.¹ of heat added. As this dilution may amount to as much as 28 gallons an hour, the strength of the solution must be tested several times each day. Sufficient chemicals must then be added to maintain the proper concentration and insure uniform removal of residue. If steam is used at a pressure of 30 pounds or more per square inch, slightly less dilution occurs. One pound of dry steam at one pound per square inch gage pressure gives up approximately 1,073.5 B.t.u. of heat to the washing solution, and one pound of dry steam at 30 pounds per square inch gage pressure gives up approximately 1,093.5 B.t.u. of heat. There is thus a slight advantage in using steam at the higher pressure.

Particular caution should be observed by operators of heating systems utilizing live steam. Without careful and constant attention by an operator who has some knowledge of boiler operation, there is some danger of an explosion. This danger is greater where higher pressures are used. The boiler must be given sufficient attention to maintain not only the correct amount of fire but also the correct water level, as the continual loss of water must be replaced.

In installing a live-steam system the steam supply pipe should be located so that the control valve (preferably a globe or needle valve) is within easy reach of the operator. This pipe should be insulated to reduce the loss of heat and consequent condensation and waste of steam. A water separator (see Fig. 1) should be provided near the washer to eliminate any water contained in the steam. The steam should be entered into the wash water at four or more points thru lengths of rubber hose extending from above the water or spray area to near the bottom of the tank. Each hose should be attached to the steam pipe thru a valve. When the steam supply is shut off, these valves should be closed to prevent the acid wash water being drawn back into the pipe and heater upon the condensation of the steam remaining in the system.

Steam-Radiator System

Steam heating systems in which radiator coils are used in the washing solution may be of two types, according to the method of handling the condensed steam. If the boiler can be placed sufficiently

¹The unit of heat used in this publication is the mean British thermal unit (B.t.u.), which is equal to 1/180 of the amount of heat required to raise the temperature of one pound of water from 32 to 212° F.

below the level of the radiator pipe, a closed system can be installed and the condensed steam returned directly to the boiler (Fig. 2). Where this is impracticable, the end of the radiator pipe is left open and the steam wasted to the sewer or collected in a container and pumped back into the boiler to maintain the correct water level.

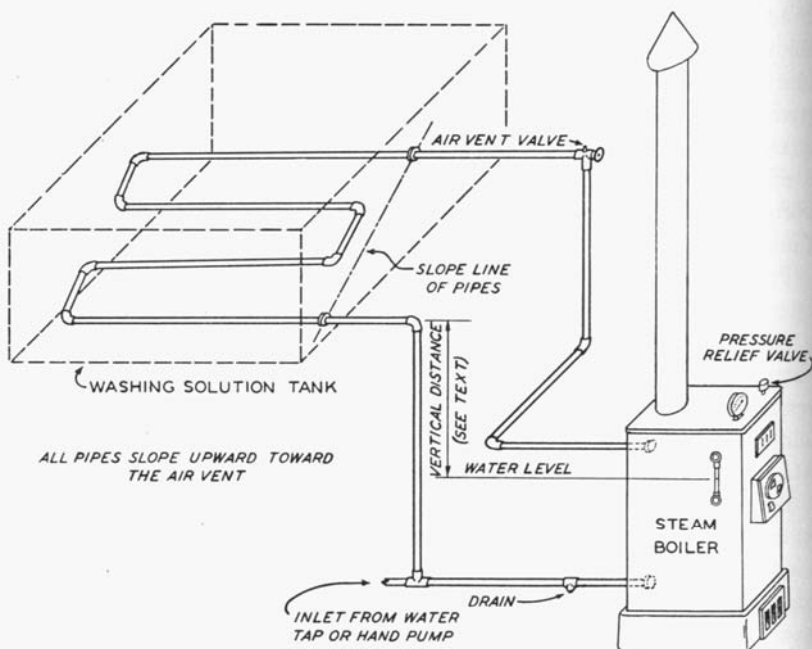


FIG. 2.—DIAGRAMMATIC VIEW OF A STEAM-RADIATOR HEATING SYSTEM

The slope line of the pipes in the washing tank as shown here is somewhat exaggerated for the purpose of showing that the pipes have a definite slope. This slope should be at least $\frac{1}{2}$ inch in 10 feet. In gravity-return steam heating systems the boiler must be located a certain minimum distance below the radiator pipe.

Details for installing steam heating systems in the various sizes and types of washers are given in Table 2. To permit the adaptation of the system to particular conditions or available materials, data are included on each of three sizes of pipe and on two classes of installations according to the horizontal distance from boiler to washer.

If a separate boiler is to be used specifically for heating the washing solution, a pipe should be selected of a size for which the minimum steam pressure listed in Table 2 is not over 2 pounds per square inch. On the other hand, if a large boiler already in use for other purposes

is available to supply steam to the washer, the pressure which will be available at the washer should be determined or estimated, and a size of pipe selected for which the minimum pressure (as shown in Table

TABLE 2.—INSTALLATION REQUIREMENTS FOR STEAM HEATING SYSTEMS USED WITH DIFFERENT APPLE-WASHING MACHINES

Model ^a	Heat required per hour	Pipe size	Length of radiator pipe ^b required	Steam pressure and vertical distance required at different horizontal distances, washer to boiler			
				When horizontal distance is 5 feet or less		When horizontal distance is 5 to 25 feet	
				Minimum steam pressure required	Minimum vertical distance required	Minimum steam pressure required	Minimum vertical distance required
	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>lbs. per sq. in. gage</i>	<i>inches</i>	<i>lbs. per sq. in. gage</i>	<i>inches</i>
USDA.....	178 361	1½	23.7	1.3	44	2.0	55
		2	18.5	1.0	30	1.0	33
		2½	15.5	.7	27	.7	28
Z.....	83 055	1	14.8	3.3	64	4.0	88
		1¼	11.3	1.0	34	1.3	40
		1½	9.6	.7	29	.7	31
X.....	216 944 ^c	1½	25.2	2.3	59	3.0	73
		2	19.7	1.0	35	1.3	39
		2½	16.5	.7	29	.7	31
E.....	86 494	1	15.5	3.0	67	4.0	93
		1¼	11.8	1.0	34	1.3	41
		1½	10.0	.7	29	1.0	32
F.....	126 111 ^c	1¼	17.1	2.0	47	2.3	59
		1½	14.7	1.0	34	1.0	40
		2	11.4	.7	27	.7	28
H.....	192 836	1½	22.4	2.0	50	2.3	62
		2	17.5	.7	32	.7	36
		2½	14.6	.5	27	.5	29
A.....	86 405	1	15.5	3.0	68	4.3	86
		1¼	11.7	1.0	35	1.3	41
		1½	10.0	.7	29	.7	32
AA.....	82 353 ^c	1	14.7	3.0	64	4.0	86
		1¼	11.2	.7	34	1.0	40
		1½	9.6	.5	28	.5	30
AD.....	113 646 ^c	1¼	15.4	1.3	44	2.0	53
		1½	13.2	.7	33	1.0	38
		2	10.3	.5	26	.5	28
ADA.....	108 459 ^c	1¼	14.7	1.0	42	2.0	50
		1½	12.6	.7	32	1.0	36
		2	9.8	.5	26	.5	27
B (31).....	82 353 ^c	1	14.7	3.0	64	4.0	86
		1¼	11.2	.7	34	1.0	40
		1½	9.6	.5	28	.5	30
B (34).....	100 683 ^c	1	18.0	4.3	82	5.3	116
		1¼	13.7	1.0	39	1.7	47
		1½	11.7	.7	31	.7	35

(Table is concluded on page 14)

TABLE 2.—*Concluded*

Model ^a	Heat required per hour	Pipe size	Length of radiator pipe ^b required	Steam pressure and vertical distance required at different horizontal distances, washer to boiler			
				When horizontal distance is 5 feet or less		When horizontal distance is 5 to 25 feet	
				Minimum steam pressure required	Minimum vertical distance required	Minimum steam pressure required	Minimum vertical distance required
	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>lbs. per sq. in. gage</i>	<i>inches</i>	<i>lbs. per sq. in. gage</i>	<i>inches</i>
C or CB (31)	145 091	1½	19.7	2.3	54	3.0	70
		1½	16.9	1.0	38	1.3	46
		2	13.2	.5	29	.5	31
C or CB (34)	154 754 ^c	1½	21.0	2.3	59	3.3	76
		1½	18.0	1.3	40	1.3	49
		2	14.0	.5	30	.5	32
D or DB (31)	204 050	1½	23.7	2.0	53	3.0	64
		2	18.5	.7	33	1.0	37
		2½	15.5	.5	28	.5	30
D or DB (34)	209 269 ^c	1½	24.3	2.3	54	3.0	67
		2	19.0	.7	34	1.0	38
		2½	15.9	.5	29	.5	30
BDP, 1st tank	116 579 ^c	1½	18.5	1.3	45	2.0	55
		1½	15.8	.7	34	1.0	38
		2	12.4	.5	27	.5	28
BDP, 2d tank	95 734 ^c	1	17.2	3.3	78	5.3	106
		1½	13.0	1.0	38	1.3	45
		1½	11.1	.5	29	.5	33
CDP, 1st tank	187 681 ^c	1½	25.6	2.0	49	2.3	61
		2	20.0	.7	32	.7	35
		2½	16.7	.5	28	.5	29
CDP, 2d tank	109 179 ^c	1½	14.8	1.3	42	2.0	50
		1½	12.7	.7	31	1.0	35
		2	9.9	.5	26	.5	27
DDP, 1st tank	253 164 ^c	1½	34.5	3.3	78	4.3	96
		2	26.9	1.3	42	1.3	48
		2½	22.6	.5	31	.5	33
DDP, 2d tank	143 885 ^c	1½	19.5	2.3	54	3.0	69
		1½	16.7	1.0	38	1.3	46
		2	13.0	.5	29	.5	31

^aSee Table 1, page 8, for detailed dimensions of the acid compartments.

^bLengths of glass-coated pipe (enameled) required for these models are approximately the same as of the painted pipes. If bare pipes (monel metal, etc.) are used, these lengths may be shortened about 20 percent.

^cHeat loss from washers alone estimated from values obtained for washers of the same type but different size.

2) is *less* than the estimated pressure at the washer. If the pressure normally carried in such a boiler is considerably in excess of that indicated in the table, the pipe used to connect the boiler and the washer may be somewhat smaller than that specified for use inside the washer.

In a gravity-return steam system the boiler must be located so that the water level in the boiler is sufficiently below the lowest portion of the radiator pipe for the water (condensed steam) in the pipes to flow back into the boiler. The minimum vertical distances for the various sizes of pipe are given in Table 2. This vertical distance is necessary in order to prevent the radiator pipes from being filled with water backed up into the water-return pipe to a height sufficient to balance the pressure generated by the steam (minus the pressure lost by the steam in overcoming the friction of the pipes) plus the pressure necessary to cause the condensed steam to flow into the boiler against the frictional resistance of the pipe.

(For further discussion of steam systems see pages 23 to 30.)

HOT-WATER SYSTEMS

Hot-water heating systems are of three distinct types—direct heating by circulating the washing solution thru a heater, the gravity-flow hot-water system, and the forced-circulation hot-water system.

Direct Heating of Washing Solution

In the West several orchardists have used systems which force the washing solution thru the water jacket of a hot-water heater. Altho this system has proved satisfactory in some cases, it is not to be recommended generally. Deposits of washing materials such as sodium silicate on the inside of the heater interfere with the normal transfer of heat and eventually clog the heater or cause it to burn out. Unless the heater is made of special acid-resisting metal, the reaction of chemicals such as hydrochloric acid with the materials of the heater make fairly frequent replacements necessary. Another objection to this type of heating system is that it requires the use of a circulating pump.

Gravity-Flow Hot-Water System

Where conditions are favorable for its use, the gravity-flow hot-water heating system (Figs. 3, 4 and 5) is the most desirable, as no circulating pump is needed and the system has a certain degree of natural regulating ability. The circulating force arises from the difference in the weights of two columns of water at different temperatures. This difference in weight depends upon the difference in temperature and the vertical length of the hot and cold water columns. As the circulating force developed in this manner is small, the system must be carefully designed. Relatively large radiator pipes with as few fittings as possible must be used in order to reduce friction and obtain

TABLE 3.—INSTALLATION REQUIREMENTS FOR GRAVITY-FLOW HOT-WATER HEATING SYSTEMS
USED WITH DIFFERENT APPLE-WASHING MACHINES

Model ^a	Heat required per hour	Pipe size	Length of radiator pipe and minimum vertical distance ^b required for three different temperature differences								
			For difference of 50 degrees F. ^c			For difference of 40 degrees F. ^c			For difference of 30 degrees F. ^c		
			Length of radiator pipe required ^d	Vertical distance required		Length of radiator pipe required ^d	Vertical distance required		Length of radiator pipe required ^d	Vertical distance required	
				When horizontal distance is 5 feet or less ^e	When horizontal distance is 5 to 20 feet ^e		When horizontal distance is 5 feet or less ^e	When horizontal distance is 5 to 20 feet ^e		When horizontal distance is 5 feet or less ^e	When horizontal distance is 5 to 20 feet ^e
	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>
USDA.....	178 361	2½ 3	55.2 46.5	4.3 1.5	5.2 1.9	50.8 43.1	8.3 2.7	10.3 3.3	39.4	6.2	7.6
Z.....	83 055	1½ 2 2½	33.3 27.9	6.1 1.5	8.2 2.1	25.4 22.6	2.7 1.1	3.9 1.5	23.1 20.3	6.1 2.5	8.5 3.4
X.....	216 944 ^f	2½ 3	56.1 48.1	6.3 2.1	7.7 2.6	43.8	4.1	4.9	40.0	7.7	9.7
E.....	86 494	1½ 2 2½	22.9 19.6	5.8 1.7	8.2 2.3	17.7 16.1	3.1 1.1	4.2 1.5	15.8 14.2	6.2 2.5	8.8 3.5
F.....	126 111 ^f	2 2½ 3	26.7 23.7	3.9 1.3	5.2 1.8	23.9 20.2 19.0	6.2 2.4 .9	8.5 3.4 1.2	19.1 16.8	5.9 2.0	8.2 2.7
H.....	192 836	2½ 3 3½	33.6 29.4	4.2 1.5	5.3 1.9	30.2 26.6 24.4	7.9 2.7 1.4	9.9 3.4 1.8	23.7 21.6	6.4 3.2	8.1 4.0
A.....	86 405	1½ 2 2½	22.7 19.6	5.2 1.4	7.4 2.0	17.7 16.1	2.6 1.0	3.8 1.4	15.6 14.2	6.1 2.5	8.9 3.6
AA.....	82 353 ^f	1½ 2 2½	21.9 18.9	4.5 1.2	6.6 1.8	19.7 17.0 15.4	8.9 2.4 .9	12.7 3.4 1.4	15.1 13.6	5.5 2.2	8.0 3.2
AD.....	113 646 ^f	2 2½ 3	24.5 22.1	2.5 1.0	3.6 1.4	21.9 19.9	4.9 1.9	6.3 2.7	17.6 15.5	4.7 1.6	6.5 2.2
ADA.....	108 459 ^f	2 2½ 3	23.6 21.2	2.3 .9	3.3 1.3	21.1 19.2	4.4 1.7	6.1 2.5	17.0 15.0	4.2 1.5	5.8 2.0

TABLE 3.—*Concluded*

	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>	<i>feet</i>
B (31).....	82 353 ^f	1½	21.9	4.5	6.6	19.7	8.9	12.7	....	....	....
		2	18.9	1.2	1.8	17.0	2.4	3.4	15.1	5.5	8.0
		2½	....	....	....	15.4	.9	1.4	13.6	2.2	3.2
B (34).....	100 683 ^f	2	22.2	2.4	3.2	19.9	4.5	6.1	....	....	....
		2½	20.1	1.0	1.4	17.8	1.6	2.3	16.1	3.6	5.0
		3	....	....	....	....	....	....	14.0	1.4	1.9
C or CB (31).....	145 091	2	29.7	5.2	6.8	....	....	....	....	....	....
		2½	26.8	2.2	2.9	24.1	4.1	5.4	21.6	8.1	11.0
		3	....	....	....	21.3	1.2	1.6	19.0	2.7	3.7
C or CB (34).....	154 754 ^f	2	31.5	6.0	7.9	....	....	....	....	....	....
		2½	28.2	2.6	3.3	25.6	4.5	5.8	22.7	9.6	13.1
		3	....	....	....	22.2	1.4	1.9	19.9	3.1	4.2
D or DB (31).....	204 050	2½	35.3	4.6	5.6	31.8	9.3	11.8	....	....	....
		3	30.9	1.7	2.1	27.9	3.1	3.9	25.0	7.2	9.1
		3½	....	....	....	25.3	1.6	1.9	22.7	2.9	3.8
D or DB (34).....	209 269 ^f	2½	36.0	4.9	6.3	....	....	....	....	....	....
		3	31.5	1.7	2.3	28.4	3.4	4.2	25.4	7.8	9.7
		3½	....	....	....	25.8	1.7	2.1	23.2	3.2	4.1
BDP, 1st tank.....	116 579 ^f	2	30.7	3.5	4.6	27.1	6.4	8.6	....	....	....
		2½	29.7	1.3	1.7	24.5	2.3	3.1	21.6	5.4	7.4
		3	....	....	....	....	....	....	19.0	1.8	2.5
BDP, 2d tank.....	95 734 ^f	1½	24.8	6.4	9.3	....	....	....	....	....	....
		2	21.3	1.7	2.5	19.2	3.3	4.7	17.1	6.6	9.9
		2½	....	....	....	17.1	1.3	1.9	15.4	3.2	4.6
CDP, 1st tank.....	187 681 ^f	2½	40.4	4.8	5.8	....	....	....	....	....	....
		3	35.4	1.5	1.8	31.5	2.8	3.5	27.9	6.2	7.7
		3½	....	....	....	28.8	1.4	1.7	25.4	3.2	3.9
CDP, 2d tank.....	109 179 ^f	2	23.8	2.4	3.4	21.2	4.5	6.4	....	....	....
		2½	21.3	1.0	1.4	19.2	1.7	2.4	17.1	4.2	5.9
		3	....	....	....	....	....	....	15.1	1.5	2.0
DDP, 1st tank.....	253 164 ^f	2½	51.6	9.7	11.7	....	....	....	....	....	....
		3	45.3	3.4	4.1	40.3	6.2	7.4	....	....	....
		3½	....	....	....	36.8	2.6	3.2	32.5	6.0	7.3
DDP, 2d tank.....	143 885 ^f	2	29.5	5.2	6.8	....	....	....	....	....	....
		2½	26.4	2.4	2.9	24.0	3.3	4.5	21.4	9.0	12.7
		3	....	....	....	21.1	1.2	1.6	18.8	2.7	3.7

^aSee Table 1, page 8, for detailed dimensions of the acid compartments.

^bMinimum vertical distance required from center of heater to center of radiator pipe.

^cDifference in temperature of heating water at intake and at outlet of radiator pipes.

^dLengths of glass-coated pipe (enameled) required for these models are approximately the same as of the painted pipes. If bare pipes (monel metal, etc.) are used, these lengths may be shortened about 20 percent.

^eFrom washer to heater.

^fHeat loss from washers alone estimated from values obtained for washers of same type but different size.

the best circulation. The heater must be located a certain minimum distance below the level of the radiator pipes. These special requirements increase the piping cost over that of other systems and limit the use of this method to those installations having a suitable location for the heater.

Data on sizes and lengths of pipes necessary for installing gravity-flow hot-water heating systems in various sizes and types of washers are given in Table 3, pages 16-17. The data in Table 3 are based on piping systems having a minimum number of pipe fittings. Unless a

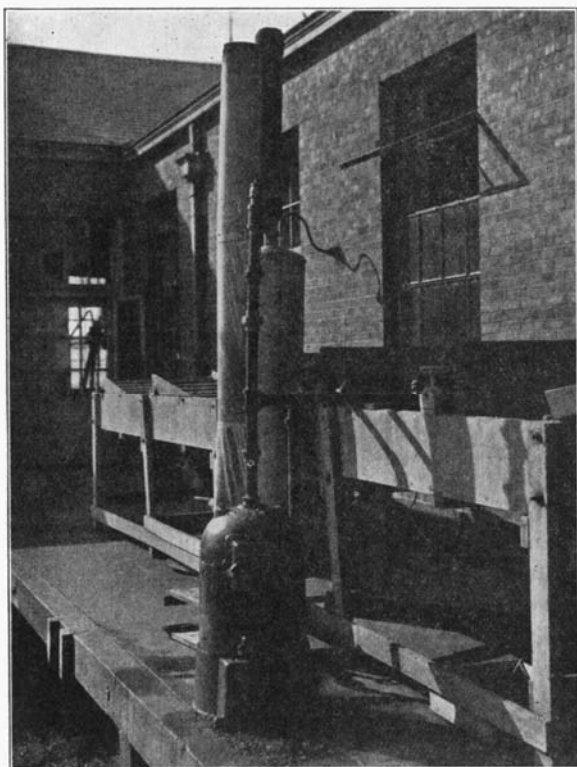


FIG. 3.—GRAVITY-FLOW HOT-WATER HEATING SYSTEM
INSTALLED IN A FLOTATION WASHER

The installation shown here could have been improved if the pipes had been brought thru the side or bottom of the wooden tank rather than over the edge as shown. Such a change would have eliminated the resistance offered by several pipe fittings and about 4 feet of connecting pipe. The expansion tank shown was used because of its availability. In order to minimize the change of water level under different operating conditions, the expansion tank should have a larger cross-section area than that shown. Furthermore the expansion tank should be installed at a level higher than that shown.

minimum number of pipe fittings are used in the actual installation, the resistance to flow may become great enough to interfere materially with the proper operation of the heating system.

In order that provision might be made for different conditions under which heaters may be installed, data are given in Table 3 for each of three sizes of pipe; for two classes of installations according to the horizontal distance between the heater and the washer; and for

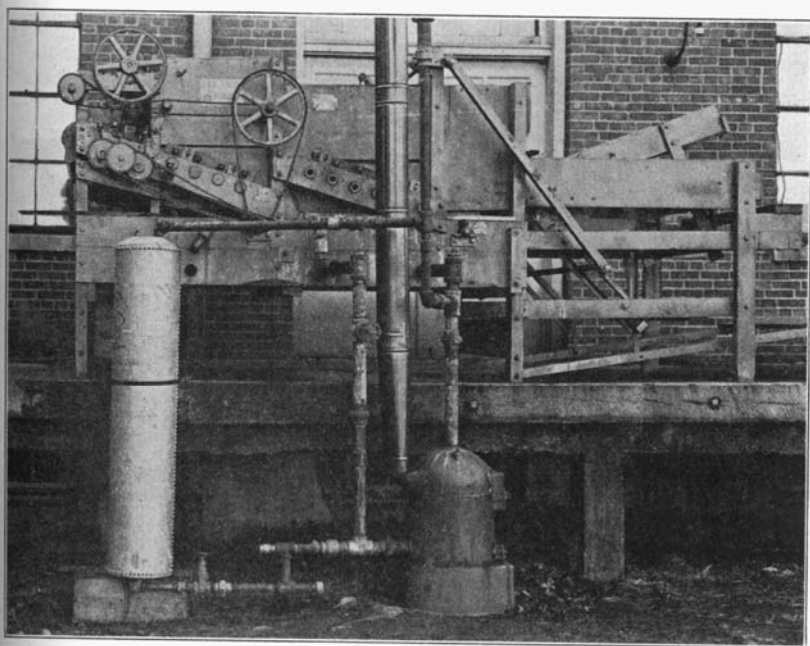


FIG. 4.—GRAVITY-FLOW HOT-WATER HEATING SYSTEM INSTALLED
IN AN UNDERBRUSH FLOOD-TYPE WASHER

In the installation shown here, as well as in that shown in Fig. 3, the expansion tank should have a larger cross-section area in order to minimize the change of water level under different operating conditions, and should be installed at a greater distance above the washer.

installations having different temperature differences between hot and cold water columns. In each of these the inlet temperature is 215°F . but the outlet temperature is 50, 40, and 30 degrees, respectively, below the inlet temperature.

Gravity-flow systems using a temperature difference of 50 degrees require the greatest length of a given size of radiator pipe, but they require at this temperature difference the least vertical distance between the center of the radiator pipe and the center of the heater.

Where smaller temperature differences, and consequently higher average temperatures, are used, the required length of radiator pipe is less, but the boiler must be installed at a lower level.

In selecting the proper size and length of pipe, and the proper location of the boiler for a particular condition, consideration should be given to the sizes of pipe available, the possible locations of the boiler, the amount of space available in the washer for installing the

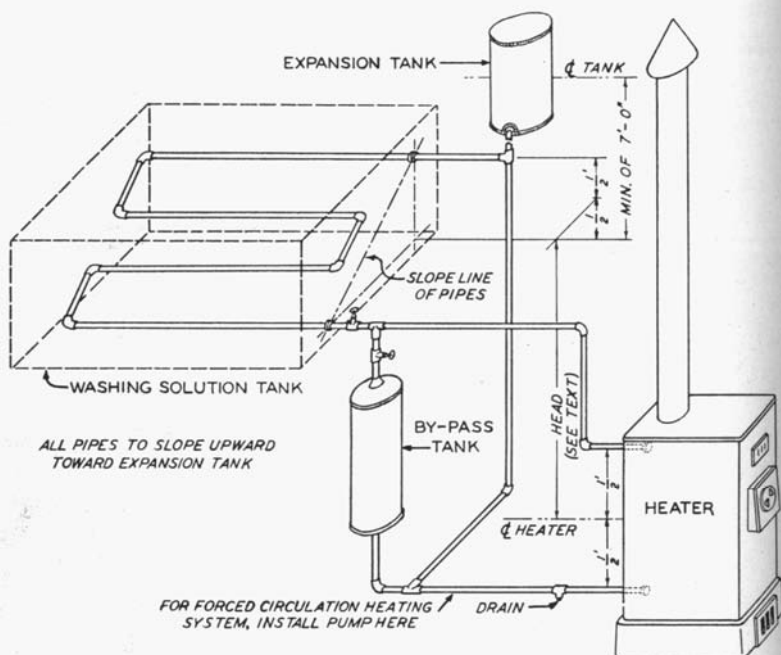


FIG. 5.—DIAGRAMMATIC VIEW OF A GRAVITY-FLOW HOT-WATER HEATING SYSTEM

The slope line of the pipes in the washing tank as shown here is somewhat exaggerated in order to show that there is a definite slope upward toward the expansion tank. The slope of the pipes should be at least $\frac{1}{2}$ inch in 10 feet.

pipe, and the relative cost of the one or more installations which could be used. (For further discussion of gravity-flow systems, see pages 23 to 30.)

Forced-Circulation Hot-Water System

The forced-circulation hot-water system is especially adapted to installations where the horizontal distance between the heater and the washer is great, or where it is necessary to locate the heater on a level with or above the radiator pipe in the washer. The heater in the forced-circulation system can be installed at any convenient point

even tho it is on a level with or above the radiator pipe in the washer. Altho this system requires the use of a circulation pump and the necessary driving mechanism, the higher velocity of the hot water permits the use of somewhat smaller and shorter radiator pipes than the gravity-flow system.

Size and length of pipe necessary in installing forced-circulation systems in the various sizes and types of washers are indicated in Table 4. Three sizes of pipe are considered in order that installation may be adapted to particular conditions or available materials.

TABLE 4.—INSTALLATION REQUIREMENTS FOR FORCED-CIRCULATION HOT-WATER HEATING SYSTEM USED WITH DIFFERENT APPLE-WASHING MACHINES

Models ^a	Heat required per hour	Pipe size	Length of radiator pipe ^b required	Velocity of flow thru radiator	Quantity of water pumped thru pipe
	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>in./sec.</i>	<i>gals./min.</i>
USDA.....	178 361	1½	63.6	34	17.9
		2	50.3	30	25.0
		2½	42.2	30	35.7
Z.....	83 055	1	37.6	37	8.3
		1¼	29.1	30	11.5
		1½	24.9	30	16.0
X.....	216 944 ^c	1½	63.2	41	21.7
		2	50.7	30	25.0
		2½	42.5	30	36.0
E.....	86 494	1	23.0	38	8.6
		1¼	18.3	30	12.3
		1½	15.7	30	16.4
F.....	126 111 ^c	1¼	26.4	32	12.6
		1½	22.9	30	16.0
		2	17.8	30	25.0
H.....	192 836	1½	33.3	38	19.3
		2	27.3	30	25.0
		2½	22.9	30	36.0
A.....	86 405	1	22.8	39	8.6
		1¼	18.3	30	12.0
		1½	15.7	30	16.0
AA.....	82 353 ^c	1	22.0	37	8.3
		1¼	17.5	30	12.0
		1½	14.9	30	16.0
AD.....	113 646 ^c	1	28.5	48	11.0
		1¼	24.1	30	12.0
		1½	20.6	30	16.0
ADA.....	108 459 ^c	1	27.2	48	11.0
		1¼	23.0	30	12.0
		1½	19.7	30	16.0
B (31).....	82 353 ^c	1	22.0	37	8.3
		1¼	17.5	30	12.0
		1½	14.9	30	16.0
B (34).....	100 683 ^c	1	25.7	45	10.0
		1¼	21.3	30	12.0
		1½	18.3	30	16.0

(Table is concluded on page 22)

TABLE 4.—*Concluded*

Model ^a	Heat required per hour	Pipe size	Length of radiator pipe ^b required	Velocity of flow thru radiator	Quantity of water pumped thru pipe
	<i>B.t.u.</i>	<i>inches</i>	<i>feet</i>	<i>in./sec.</i>	<i>gals./min.</i>
C or CB (31).....	145 091	1¼ 1½ 2	29.6 26.3 20.5	36 30 30	14.5 16.0 25.0
C or CB (34).....	154 754 ^c	1¼ 1½ 2	31.0 28.1 21.9	39 30 30	15.5 16.0 25.0
D or DB (31).....	204 050	1½ 2 2½	35.0 28.9 24.2	39 30 30	20.4 25.0 36.0
D or DB (34).....	209 269 ^c	1½ 2 2½	35.7 29.6 24.8	40 30 30	20.9 25.0 36.0
BDP, 1st tank.....	116 579 ^c	1¼ 1½ 2	29.5 25.4 19.8	31 30 30	12.0 16.0 25.0
BDP, 2d tank.....	95 734 ^c	1 1¼ 1½	24.7 20.3 17.4	43 30 30	9.6 12.0 16.0
CDP, 1st tank.....	187 681 ^c	1¼ 1½ 2	42.8 40.1 31.9	48 33 30	18.8 18.8 25.0
CDP, 2d tank.....	109 179 ^c	1 1¼ 1½	27.3 23.2 19.8	48 30 30	10.9 12.0 16.0
DDP, 1st tank.....	253 164 ^c	1½ 2 2½	49.4 43.0 36.0	48 48 30	25.3 25.3 36.0
DDP, 2d tank.....	143 885 ^c	1¼ 1½ 2	29.4 26.1 20.4	36 30 30	14.4 16.0 25.0

^aSee Table 1, page 8, for detailed dimensions of the acid compartments.

^bLengths of glass-coated pipe (enameled) required for these models are approximately the same as of the painted pipes. If bare pipes (monel metal, etc.) are used, these lengths may be shortened about 20 percent.

^cHeat loss from washers alone estimated from values obtained for washers of same type but different size.

The forced-circulation systems described herein were designed on the basis of the following conditions:

1. Average temperature in the radiator pipe, 200° F.
2. Minimum water velocity, 2½ feet per second.
3. Maximum difference in temperature between the radiator pipe inlet and outlet, 20 degrees.
4. A low power requirement for circulating the hot water.

Unless the piping system is unusually long or poorly installed, or the pump too small or otherwise unsuitable, a ⅙- or ¼-horsepower motor (electric) should be large enough for all heating loads. Even tho the power required is small, the amount of water to be pumped in forced-circulation systems is relatively large, and a large pump is required. On some washers the pump may be driven from one of the

washer shafts, in which case a separate source of power is not necessary. The pump should be installed between the radiator pipe and the heater, and should always be below the level of the radiator pipe (Fig. 5).

If the pump to be used with the forced-circulation system is to be purchased for this particular use, the piping system should be installed or decided upon before the order for the pump is placed. In ordering a pump the following should be specified:

A pump capable of circulating gallons of water per minute at an average temperature of approximately 200° F., at a velocity of inches per second, in a closed heating system consisting of one heater and feet of pipe, elbows, tees, and valves, all pipes and fittings being inches in diameter.

If a pump already on hand is to be used in the system, some experimenting should be done to determine a suitable pump speed. The proper speed is best indicated by the temperature of the water entering and leaving the radiator pipe. If the difference between these two temperatures is between 5 and 20 degrees F., the pump speed is approximately correct. If the temperature difference is less than 5 degrees, the pump is being operated unnecessarily fast. If the temperature difference is greater than 20 degrees, the pump should be operated at a higher speed.

INSTALLATION DETAILS FOR STEAM AND HOT-WATER HEATING SYSTEMS

Heaters and Boilers

Hot-water heaters and steam boilers vary considerably in efficiency, cost, and capacity, and the unit best adapted to a given set of conditions is determined by these factors.

The first step in selecting a heater or boiler is to determine, from Table 5, the basic size of heating unit to be used, that is the heater or boiler which supplies a B.t.u. output per hour nearest to the requirement of the particular type and size of washer used (Table 1). It is, however, possible to force most heaters and boilers to carry heat loads two or even three times their rated outputs, and under some conditions it may be profitable for growers to install units smaller than the basic size.

If the cost of fuel and labor in a given community is low as compared with the original cost, depreciation, repairs, etc., of the heating unit, a heater rated as low as one-half to one-third of the basic size may be selected in order to reduce the amount invested in

the heater. Or, if the washer is to be used only a few days each year, the high fuel and labor cost of operating a small inefficient unit requiring more or less constant attention may be justified by the saving in investment made by installing a small heater or boiler.

The purchase of a new heater is not always necessary. To determine whether a heater already available is of suitable size for the purpose intended, its capacity can be roughly estimated by comparing the diameter of the grate with those listed in Table 5. If this comparison indicates that the rated capacity of the available heater is greater than one-half or one-third of the required capacity, it will probably be suitable for use.

TABLE 5.—GRATE SIZE, RATED CAPACITY, AND RATED B.T.U. OUTPUT PER HOUR FOR HOT-WATER HEATERS AND STEAM BOILERS

Capacity	Grate diameter	Rated capacity in square feet of equivalent radiation		Rated heat output per hour
		Hot water	Steam	
<i>gals.</i>	<i>inches</i>	<i>sq. ft.</i>	<i>sq. ft.</i>	<i>B.t.u.</i>
100.....	11	80	.....	12 000
150-250.....	11-13	160	.....	24 000
300-400.....	13-15	275	.....	41 280
	16-18	600	350	90 000
	18-22	850	500	127 500
	22-24	1 300	775	195 000
	24-28	1 575	950	236 250
	28-30	1 975	1 200	296 250
		2 200	1 300	330 000
		2 900	1 800	435 000
		3 500	2 125	525 000
		4 000	2 450	600 000

In the past many steam boilers have been rated in boiler horsepower. Altho this term has had a variety of meanings, it will probably be satisfactory for the present purpose to assume one boiler horsepower to be equal to the development of 33,480 B.t.u. per hour.¹ Consequently, in estimating the heating capacity of an old boiler and its adaptability to a particular washer, the boiler-horsepower rating may be multiplied by 33,480, and the resulting B.t.u. per hour capacity compared with the required amount of heat for that washer.

¹This is the same as the equivalent evaporation of 34.5 pounds of water from and at 212° F. per hour, the definition of boiler horsepower given by the Committee on Boiler Testing of the American Society of Mechanical Engineers.

Prevention of Pipe Corrosion

All ordinary steel or iron pipe undergoes corrosion when in contact with dilute hydrochloric acid. These corrosive effects are accelerated at higher temperatures. Sometimes the action proceeds at a comparatively slow rate, while in other presumably similar cases the action is so rapid that the pipe may last only a few days.

Various paints for protecting steel pipes against corrosion by acid are available on the market. In tests of the protective value of these paints, it has been found that none will protect pipe threads and pipe fittings for any great length of time. Several paints have, however, proved satisfactory on straight lengths of pipe installed in a solution tank in such a manner as to prevent the washing solution from reaching the threads and fittings (Fig. 6). When pipes are installed in such a manner, requiring a row of several large holes bored thru the side of a wooden tank, it is necessary to use one or more clamps to prevent the side from splitting lengthwise thru the holes.

Special care was used in preparing the pipes for use in the corrosion-resistant paint tests: (1) all rough places were filed smooth; (2) all loose rust and scale were removed with a wire brush; (3) the pipes were washed first with gasoline and then with soap and

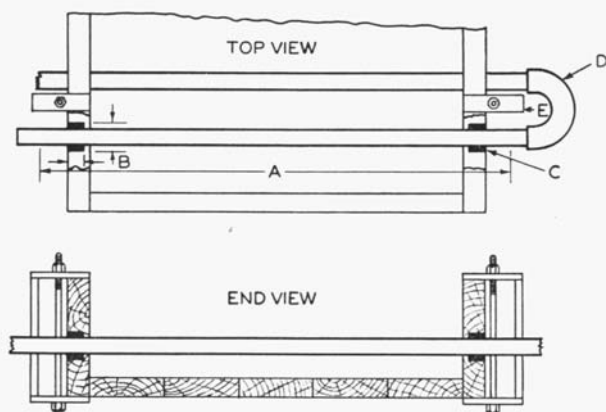


FIG. 6.—CROSS-SECTIONS OF WOODEN SOLUTION TANK, SHOWING METHOD OF INSTALLING PAINTED, GLASS-COATED, OR ALLOY METAL PIPES THRU THE WALLS

(A) Paint or glass coating should extend 2 to 3 inches beyond the outside of the tank. (B) Hole for pipe packing should be 1 inch larger in diameter than the pipe and extend two-thirds of the distance thru the tank wall. (C) Oakum packing hammered into place. (D) Ordinary return-bend or elbows (connections may be made with sections of steam hose). (E) Clamp to prevent the tank wall from splitting.

water and finally were given a thoro rinsing; (4) shortly before being painted, the pipes were rubbed with a clean cloth dipped in naphtha; and (5) a minimum of three coats of paint was applied.

In practice it is advisable to paint and have ready for use several more pipes than the number actually required in the washer at any one time. These additional pipes can be used to replace those which are defective or damaged in handling or that deteriorate in service.

Tests indicate that copper tubing would last much longer than iron or steel pipe, tho its exact life would be difficult to predict, as the copper is dissolved slowly, and local action, or pitting, takes place.

Tests with glass-coated (enameled) pipe indicate that the glass coating will last for many years if protected from mechanical injury. No detailed heat-transfer tests have been made with this kind of pipe, but observations indicate that the rate of heat transfer is approximately the same as for medium to heavily painted pipes.

Monel-metal pipe has been used by some western orchardists in an effort to avoid corrosion of pipes. Tests have indicated that some general, as well as local, corrosion takes place, but that this corrosion is probably not rapid enough to prevent the alloy from lasting thru two or more seasons. If the heating pipes are installed as shown in Fig. 6, common iron pipe fittings can be used outside the tank, so that expensive monel-metal fittings will not be needed. Tests on rate of heat transfer indicate that a bare monel-metal pipe approximately 20 percent shorter than a painted pipe of the same diameter will give off the same quantity of heat.

Heating Two or More Washing Tanks With One Boiler

Sometimes it is desirable to heat from the same boiler both washing tanks of tandem or double-process washers or the several washing tanks of a number of single-process washers. This may be done satisfactorily if certain requirements are met in laying out and installing the entire heating system.

All solution tanks heated from one boiler must be supplied with the same type of heat, tho not necessarily by the same type of heating system. Thus, if steam heat is used, some tanks may be heated with "live steam," while others are heated with a steam-radiator system. Similarly, if hot water is used, some tanks may be supplied by a gravity-flow system and others by a forced-circulation system.

When the type of heat has been selected and the system to be used in each tank decided upon, the installation in the various tanks may be made as if each were the only one to be considered.

The location of the boiler is important in certain types or adaptations of heating systems (see pages 5-6). A boiler supplying more than one solution tank should be located at least as far below the lowest tank as the greatest distance specified for any one of the tanks (Tables 2 and 3).

Connecting pipes between the boiler and the washing tanks should be large enough to supply all washing tanks with an adequate amount of steam or hot water. When a boiler is used to heat only one tank, it is customary to connect the two by pipe of the same size as that specified for a radiator heating system for the tank. Where more than one tank is heated by one boiler, the same size of pipe specified for each tank may also be used if the tanks are located in opposite directions from the boiler. It is frequently desirable, however, to use one main supply pipe with branch pipes to each individual solution tank. The cross-sectional area of the main supply pipe at any particular point should be at least as large as the sum of the cross-sectional areas of all branch pipes beyond that point.

Length of Radiator Pipe

The radiator pipe may be adjusted somewhat in length to enable the pipe coils to be fitted into the space available in the washing tank. The heating system will usually operate satisfactorily even tho the radiator pipe is made as much as 5 or even 10 percent longer or shorter than that specified in Tables 2, 3, and 4.

By-Pass Tank

Provision should be made in the heating system for cutting off the heat if the washing solution becomes too hot. Altho overheating is not a major problem, it is advisable to provide a means for minimizing the delay and damage resulting when it does occur.

To meet this problem of overheating, a by-pass tank was installed in each of the systems shown in Figs. 3 and 4 so that the hot water (or steam) could be diverted temporarily from the washer until the solution cooled down or the fire was drawn. The by-pass tank is a large piece of pipe or a tank of 10 or more gallons capacity connected to the system with pipe at least half the diameter of the radiator pipe (not less than $\frac{3}{4}$ inch). In steam systems the by-pass tank should be located above the water level in the boiler.

A gate valve should be installed in the washer circuit and another in the by-pass tank circuit to control the flow of steam or water. The exact location of these valves is not important providing they do not

interfere with the main circuit, the path to the expansion tank, or the circulating pump, if one is used.

Drains and Vents

Sufficient drain plugs should be installed in all heating systems to provide complete drainage during cold weather.

In a steam system the radiator pipes must slope *downward* toward the *outlet end* by not less than $\frac{1}{2}$ inch in each 10 feet, to prevent water collecting in the low spots and obstructing the flow of steam. If such an installation is impossible in a return steam system, the low parts of the radiator pipe should be connected by $\frac{3}{8}$ - or $\frac{1}{2}$ -inch pipe to the return pipe well below the water line.

One or more vents should be provided in a return steam system to permit the venting of entrapped air. When the system is cooling, these vents should be opened to prevent a vacuum being created and the possibility of acid wash water being drawn into the pipes and heater.

In a gravity-flow hot-water system the radiator pipes should slope *upward* toward the *outlet end* by not less than $\frac{1}{2}$ inch in each 10 feet, to prevent air collecting in pockets in the pipe and obstructing the flow of water. Automatic or manually operated vents for releasing the entrapped air should be placed at all high points in the pipe.

In a forced-circulation hot-water system the higher velocity of flow usually prevents the formation of objectionable air pockets at slightly irregular points in the pipe, and thus permits the use of one automatic or hand-operated vent. A short section of pipe ending in a valve and connected at the highest point between the heater and the radiator pipe will usually permit the venting of all entrapped air in forced-circulation systems.

Temperature-Control Equipment

Temperature-control equipment for steam or hot-water heating systems is usually designed to regulate the opening of the draft to the heater. The control system may operate from changes in the temperature or pressure of the steam or water leaving the boiler, or it may be installed in the washing solution where it will operate from changes in the temperature of the solution itself.

Automatic temperature-control equipment is merely an aid to the operator in controlling the heater—it neither adds fuel to the fire nor maintains it in the proper burning condition. Particularly in installations using a boiler that is small in relation to the heating load, the

fire must be forced most of the time, and there is very little opportunity for automatic controls to be of any great value.

Decreasing the Heat Loss From Washers

The normal heat loss from flotation washers cannot be decreased to any great extent except by increasing the temperature of the room in which the washer is located. The warming-up time can be shortened, however, if the washer is covered with canvas or boards during this process.

In flood-type washers the greatest loss of heat takes place from the water as it is sprayed thru the air. In a test on the underbrush flood-type washer, this loss was reduced approximately 15 percent by a more complete enclosing of the sides of the washer as shown by the unpainted boards in Fig. 4. Considerable care must be exercised in enclosing a washer of this type, to provide proper drainage for the washing solution following the brushing rolls. If the enclosure is not properly made, this water will drain to the outside of the tank rather than to the inside.

Pipe Insulation

Connecting pipes in live-steam systems should always be insulated to minimize the amount of steam condensed and added to the washing solution as water. Insulating the exposed pipes of other systems is of uncertain value.

When the systems are used for a considerable period of time each year, or have heaters very limited in capacity or connecting pipe unduly long, some form of insulation on the pipes may prove profitable. For this purpose commercial asbestos pipe covering, sheet asbestos, ordinary cloth or paper, or any commercial flexible insulating material may be used. Aluminum bronze paint will reduce the loss of heat to some extent and at the same time protect the pipes against corrosion.

Pipe Cutting and Reaming

Pipe cut with a plumber's pipe cutter is burred-in at the end to such an extent that the resistance to the flow of water or steam is greatly increased. In systems having a large number of short pipes the presence or absence of these burrs may determine whether the system will operate properly. All burrs should be removed with a pipe reamer or round file.

Expansion Tank

As water expands when heated and contracts when cooled, some form of expansion tank must be provided to protect a hot-water

system from damage. The location of the expansion tank governs the maximum temperature that can be maintained in the system without boiling.

If city water or water from a storage tank is available, the heating system can be connected directly to the water mains, and the water system then serves as an expansion tank. If such a supply system is not available, a tank of 3 or more gallons capacity should be connected to the system by a $\frac{1}{2}$ -inch, or larger, pipe. An expansion tank located 7 feet above the level of the radiator coils permits a maximum temperature of 220° F. to be maintained in the system without boiling, and a tank 15½ feet above the coils permits a temperature of 230° F. without boiling. In any hot-water system the expansion tank should be at least 7 to 10 feet above the radiator coils.

In forced-circulation systems the pipe from the expansion tank should be connected to the return pipe from the washer just back of the *inlet to the circulation pump*. In gravity-flow systems in which a temperature above 210° F. is to be used, the connection should be made just back of the *inlet to the heater*. In other gravity-flow systems the expansion tank should be connected to the highest point of the pipe on the hot-water side of the heater so that air or steam liberated in the heater will escape thru the expansion tank.

Thermometer Wells

In hot-water heating systems it is advisable to install thermometer wells in the pipes entering and leaving the washer. Ordinary glass thermometers placed in these wells indicate the operating condition of the heating system much more accurately and much sooner than the thermometers in the wash water. By this means the operator can frequently anticipate a change in the temperature of the wash water and adjust the heater before the change becomes apparent in the washing solution itself.

In constructing a thermometer well, a piece of $\frac{1}{2}$ -inch copper or brass tubing about 3 inches long is closed at one end and soldered. The other end is soldered into the back side of a $\frac{1}{4}$ -inch by $\frac{3}{8}$ -inch galvanized pipe bushing. This bushing is then screwed into a tapped hole in the heating-system pipe, or into a tee or cross located at a convenient point. A layer of electrician's tape around the stem of the thermometer at the proper point will hold the thermometer in the well and seal the opening against excessive loss of heat.

APPENDIX: METHODS USED IN ANALYZING HEAT LOSSES AND TRANSFERS

Determining Amount of Heat for Washing Solutions

In determining the amount of heat required to maintain the washing solution in an apple-washing machine at the proper temperature during the washing process, the total heat required was separated into (1) the amount necessary to maintain the solution at the given temperature when the machine was being operated but no apples were being run thru, and (2) the amount absorbed and carried away by the apples in passing thru the washer. The reasons for using this method were the following:

1. Accurate tests could be made in a short period of time.
2. As the amount of heat lost or absorbed is a mathematical function of the difference in temperature between the solution and the outside air or apples, a relatively few tests would give data usable over the entire range of operating conditions.
3. From the data obtained, total heat requirements for any combination of operating conditions could be calculated without making a long series of tests.
4. Constant conditions could be maintained for short periods much easier than for long periods.
5. Few apples would be required for the tests.
6. Only a small crew would be required.
7. Because tests could be made before or after the harvesting season, the tests could be made on washers owned by growers.

Determination of Heat Lost by Washers

In determining the normal unit heat loss (B.t.u. per hour per degree Fahrenheit temperature difference between outside air and washing solution per square foot of exposed tank area) from each of the washers, the following procedure was used: The washing solution was heated to a temperature considerably above 110° F., the fire was dropped thru the grate and extinguished, and the valves in the connecting pipes were closed to prevent circulation of the water. After the entire system had reached a stable temperature, the temperatures of the washing solution and of the outside air were taken. After the elapse of a suitable period of time these temperatures were again taken.

From the amount of heat given off by the known body of water in the given time, the total over-all rate of loss of heat per hour per degree Fahrenheit difference in temperature between the washing solution and the outside air was computed. The values obtained for the washers tested are listed in Table 6. In addition, values for the unit heat loss are given in order that the total heat loss for washers not listed may be calculated.

In using the heat-loss data obtained from the three sizes of flood-type washers for estimating the heat loss for similar washers of a different size, the values for the three washers tested were plotted against the area of exposed tank surface and the unit-heat-loss values for similar washers of intermediate size were then taken from the curve. In estimating the unit heat loss for the intermediate size of underbrush flood-type washer from

TABLE 6.—HEAT LOSSES RECORDED IN TESTS ON APPLE-WASHING MACHINES

Model	Type	Dimensions of acid compartment				Exposed surface area	Washer heat loss	
		Tank		Tray			Total	Per square foot
		Width	Length	Width	Length			
		<i>inches</i>	<i>inches</i>	<i>inches</i>	<i>inches</i>	<i>sq. ft.</i>	<i>B.t.u./hr./deg. F.</i>	<i>B.t.u./hr./deg. F.</i>
USDA...	Flotation.....	34	171	....	....	40.3	230.3	5.7
Z.....	Flotation with pump...	24¼	109	....	....	18.4	291.8	15.8
Exp'l ^a	Underbrush with pump..	23¾	49¼	....	....	8.1	288.1	35.5
A.....	Flood.....	49½	54	....	....	18.3	751.5	41.1
C.....	Flood.....	60½	41 ⅝	57¼	43	34.6	1 110.0	32.1
D.....	Flood.....	66	48	62¾	61½	48.8	1 326.6	27.7
E.....	Underbrush flood.....	45	39¼	....	....	12.3	915.5	74.6
H.....	Underbrush flood.....	56½	81½	....	....	31.9	1 794.8	56.3

^aNot a commercial model, but a small experimental machine.

the values found for the smallest and largest sizes, a curve of the same shape as that found to apply to the flood-type washers was used. While a curve of this shape may not be applicable to both types of washers, it appeared logical to assume that it would represent the relationship as accurately as any other arbitrarily selected curve.

Determination of Heat Absorbed by Apples

The method used in determining the amount of heat absorbed by the apples in passing thru apple-washing machines was to measure the increase in temperature at various points within the apples as they were immersed in hot water and calculate the amount of heat thus absorbed. This method was selected for the following reasons:

1. By taking readings over a period of several minutes, data could be obtained to represent all possible speeds of washing (immersion time).
2. Data representing very short immersion periods could be obtained with practically the same accuracy as data for longer periods.
3. The results secured would be practically independent of the size and shape of the apples used.
4. A minimum amount of time would be required.
5. Only commonly available equipment was required.

In making the tests for heat absorption, a pointed thin glass tube filled with ambroid cement and containing a No. 30 B. & S. gage chromel and constantan thermocouple was inserted into the apple so as to be imbedded approximately 2 inches, with the point at the desired location with reference to the opposite surface of the apple. In order to minimize the conduction of heat along the couple wires, approximately ½ inch of the apple around the entrance of the wires was kept above the surface of the water, and thus a comparatively thick layer of apple was interposed between the wire and the water at all points except at the couple junction.

Each apple tested was moved back and forth at a moderate speed in the water bath accurately maintained at 110° F. by occasional additions of hot water. Temperature readings were taken at 15-second intervals for a period of five minutes by means of a portable precision potentiometer. At the end of the five minutes the apple was cut open and the exact location of the couple junction determined.

Temperatures taken at various depths in apples immersed and agitated in water at 110° F. for periods of five minutes are shown in Fig. 7. The apples used in determining the upper set of curves had been stored at room

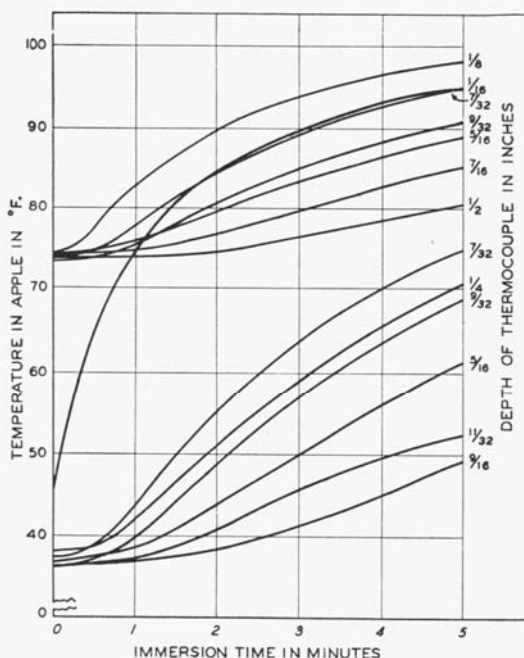


FIG. 7.—RATE OF HEAT PENETRATION IN APPLES IMMERSSED AND AGITATED IN A WATER BATH MAINTAINED AT 110° F.

temperature for one day and were at approximately 74° F., whereas the apples used in determining the lower set of curves had been in cold storage and were at approximately 36° F. The fact that about the same amount of time was required to prepare the cold-storage apple used in the test made 1/16 of an inch below the surface (in Fig. 7) as for the remaining cold-storage apples indicates that this apple had an initial temperature more nearly identical with that of the other cold-storage apples than is indicated by the initial-temperature reading.

Temperatures at various depths in apples immersed for periods of 20 to 240 seconds are shown in Figs. 8 and 9. These curves are extended to 110° F. at zero depth even tho the surface temperature was known to have been slightly less than 110° F.

In determining the amount of heat absorbed by the apples, the apples were assumed to be spheres $2\frac{1}{2}$ inches in diameter composed entirely of water. A spherical shape appeared to be as representative of various kinds of apples as any other regular shape that might have been selected. The assumption that the apples were composed entirely of water was made for three reasons: (1) the specific heat of an apple is but slightly less than the specific heat of water; (2) altho the specific heat of the apple was not used, the rate of temperature rise in the apple, as determined here, was actually a function of the specific heat of the apple; and (3) the small error involved was on the side of making the heating systems more dependable.

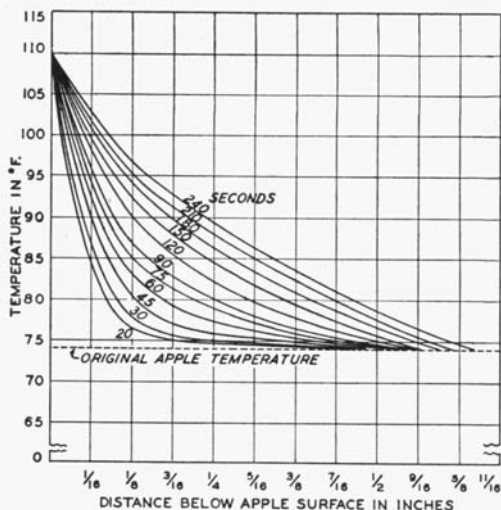


FIG. 8.—TEMPERATURE GRADIENT IN APPLES (74° F. INITIAL TEMPERATURE) IMMERSSED AND AGITATED FOR DIFFERENT PERIODS OF TIME IN A WATER BATH MAINTAINED AT 110° F.

As a means of determining the B.t.u. absorbed by the apples, an apple was considered as being divided into a series of hollow spheres each having a shell $1/16$ inch thick. The average temperature of each of these spheres was determined from the curves in Figs. 8 and 9. The heat absorbed by each sphere was calculated from the average temperature and the volume, and was used to obtain the curves plotted in Fig. 10.

As an indication of the amount of heat retained by the apples after being washed in hot water and rinsed in cold water, some of the apples initially at 74° F. were immersed and agitated in water at 110° F. for five minutes and then transferred immediately to water maintained at 55° F., and the temperature readings continued for five minutes. The temperature curves thus obtained are shown in Fig. 11. Altho these results are not identical with those obtained in actual washing, they do indicate to some extent the amount of heat which will be removed by rinse water at ground temperature. When specific conclusions in regard to a particular washing

machine are drawn from the curves in Fig. 11, the ratio of actual washing time to rinsing time in the machine used should govern the ratio of washing time to rinsing time considered on the curves. Rinsing time of most commercial machines is approximately half the washing time.

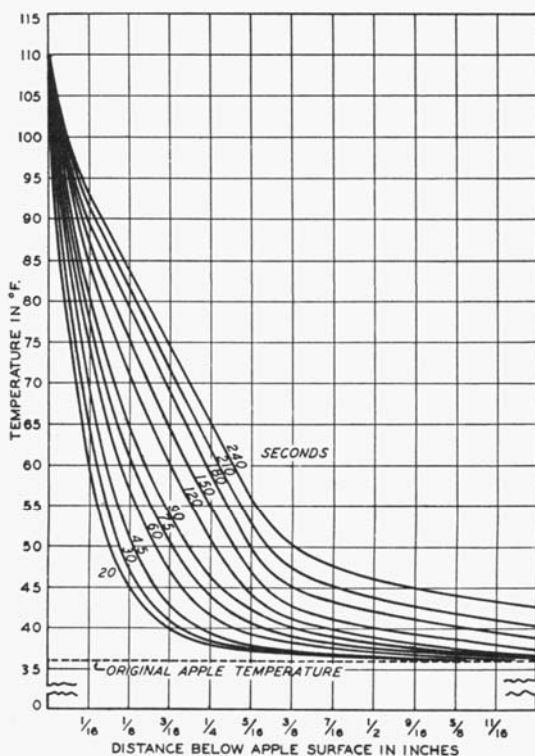


FIG. 9.—TEMPERATURE GRADIENT IN APPLES (36° F. INITIAL TEMPERATURE) IMMERSED AND AGITATED FOR DIFFERENT PERIODS OF TIME IN A WATER BATH MAINTAINED AT 110° F.

Determination of Heat Transfer Thru Painted Pipes

Mollier's formula¹ was used in determining the overall heat transfer thru asphalt-painted radiator pipes. In using this formula for the design of hot-water heating systems, the velocity of liquid flow across the outside of the radiator pipes was used as the variable factor.

The installations shown in Figs. 3 and 4 were made on the basis of assumed values for the heat transfer thru the radiator pipes, or in other words, assumed values for the velocity of flow of fluid across these pipes.

In determining the actual existing value for the flow of the liquid, the washing solution was heated to a temperature somewhat above 110° F. and

¹For the constants used, see page 407, Mark's Handbook (3d edition).

heating was continued until stable conditions were reached. Assuming that the temperature of the wash water was neither increasing nor decreasing, the heat loss from the washer equaled the overall heat transfer from the radiator pipe. As the temperature of the heating water entering and leaving the radiator pipe was known, the transfer coefficient could be calculated.

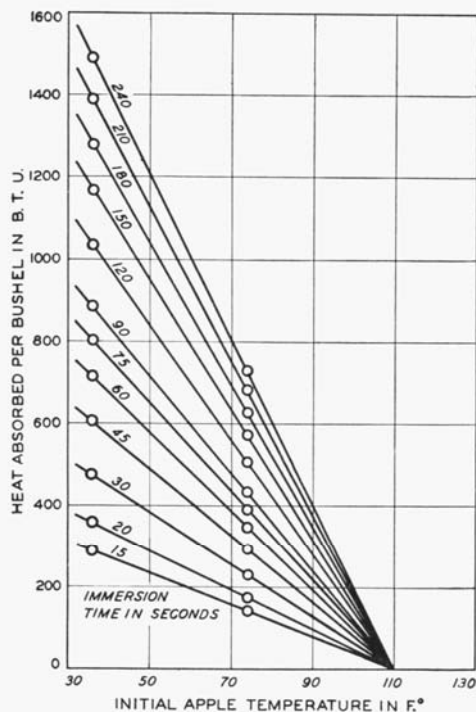


FIG. 10.—HEAT ABSORBED BY APPLES OF DIFFERENT INITIAL TEMPERATURES WHEN WASHED FOR DIFFERENT PERIODS OF TIME IN WASH WATER MAINTAINED AT 110° F.

As a means of checking whether the system was operating under stable conditions during the determination of the heat transfer, the pressure head developed by the hot and cold water columns was obtained.¹ This known pressure head was then compared with the friction head that would have been offered by the pipe were it operating under the conditions indicated by the total heat loss of the washing machine.² When these two values

¹See page 373, American Society of Heating and Ventilating Engineers Guide (8th edition).

²See pages 374 and 375, American Society of Heating and Ventilating Engineers Guide (8th edition).

were in relatively close agreement, the operating conditions were assumed to be stable and the results obtained were assumed to be sufficiently accurate for the purpose intended.

Tests on the nonagitation flotation washer showed that the heat transfer corresponded to a velocity of flow along the heating pipes of approximately $\frac{1}{4}$ inch per second. Tests made on an agitation flotation washer indicated a velocity of flow of approximately .8 inch per second, whereas similar tests on an underbrush flood-type washer indicated a velocity of flow of approximately 9 inches per second.

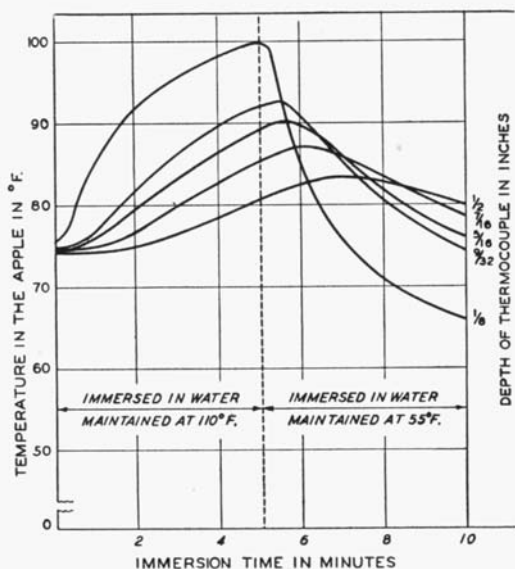


FIG. 11.—TYPICAL SET OF HEATING AND COOLING CURVES FOR APPLES WASHED IN HOT WATER AND RINSED IN COLD WATER